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Ferroelectric and Dielectric Investigations of Bismuth Ferrite ($BiFeO_3$) Nanoceramics

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ABSTRACT

In this paper we report the synthesis of $BiFeO_3$ ceramics by solid state reaction method. The X-ray analysis depicts the $BiFeO_3$ sample have rhombhohedral perovskite structure. The ferroelectric measurement shows $BiFeO_3$ ceramic exhibits ferroelectric nature with saturation, remnant polarizations of P_s = 0.26 μC/cm^2, P_r = 0.11 μC/cm^2 respectively. The dielectric constant and loss as a function of temperature (30-325^{o}C) in the frequency range 10 kHz-1MHz shows that the dielectric constant and loss increases with increasing temperature. The room temperature dielectric measurement with frequency reveals the dielectric constant and loss decreases with increasing frequency for $BiFeO_3$ ceramics.

Keywords: $BiFeO_3$ Ceramics, Solid State Reaction, Characterizations, Measurements.

INTRODUCTION

Multiferroic materials possess simultaneous existence of electric and magnetic nature together in a single phase [1-2]. These multiferroics have potential applications in information storage [3], microelectronics [4], memories, spintronic, magnetoelectric sensor devices [5], multiple state memory devices [6] and magnetoelectronics [7]. In this novel class of materials, there exists a strong coupling between magnetic and electric order parameters which results into the co-existence of ferromagnetism and ferroelectricity in a single phase, results in the production of magnetoelectric effect in the material. In ME effect a polarization can be induced by application of magnetic field and magnetization can be induced by application of electric field [8]. These materials have potential applications for many devices from the technological point of view.$BiFeO_3$ have ferroelectric Curie temperature Tc = 830^0 C and antiferromagnetic Neel temperature T_N = 370^0 C [9].

The objective of this work to determine the ferroelectric and dielectric properties of $BiFeO_3$ ceramics synthesized by a simple solid state reaction.

MATERIALS AND METHODS

2.1 Synthesis of $BiFeO_3$

The $BiFeO_3$ sample was prepared by a standard solid state reaction using Bi_2O_3 (Hi-Media Chemical, India), Fe_2O_3 (Sigma Aldrich) as a starting materials. Firstly the Bi_2O_3 and Fe_2O_3 in stiochiometric ratios were thoroughly mixed in a stiochiometric ratios and Ball milled for 24 hrs. The mixture was calcined at 650^0 C for 1hr and then powder was ground and cold pressed into pellets and sintered at 700^0 C for 1 hour. Finally these pellets were carried out for further characterizations and measurements.

2.2 Characterizations

The sintered pellets were characterized by x-ray diffraction (XRD) using CuKα radiation (λ=1.54178) (Philips X-pert PRO) for phase identification in the 2θ range (20-60^o). The surface morphological studies were addressed by using SEM (EVO-50). Dielectric measurement was performed on H.P. Impedance analyzer (4192A LF) in the frequency range of 10 kHz to 1 MHz with variable temperature range from 30 - 400 ^{o}C and the dielectric constant as a function of frequency measurement was carried out by Precision Impedance analyzer (Agilent 4294 A) at room temperature. The ferroelectric measurement was carried at room temperature on ferroelectric tester (Radiant Precision Premier II Technology) at 10 Hz. All measurement were carried on a sintered pellets polished with a thin layer of silver paste fired at 350 ^{o}C for 30 min. The silver layer act as an electrode.

RESULTS AND DISCUSSION

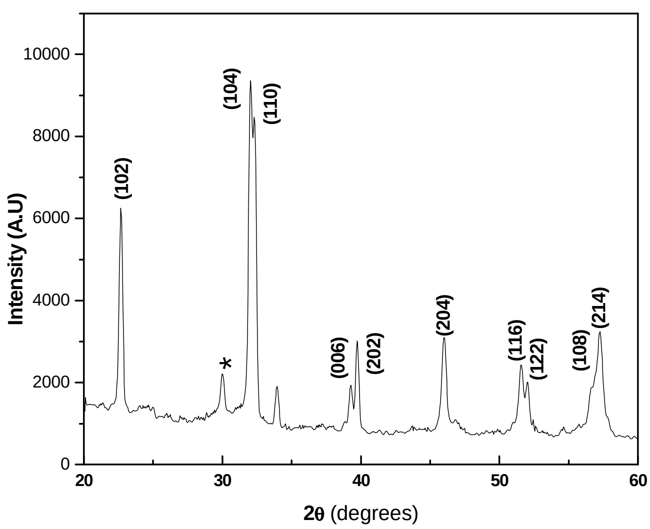

Fig.1. XRD spectra of $BiFeO_3$ [* $Bi_2Fe_4)O_9/Bi_2O_3$]

3.1 Structural Studies:
Fig.1. shows the XRD pattern of $BiFeO_3$ at RT. The XRD results showed that the $BiFeO_3$ have rhombhohedral perovskite structure with space group R3c. Typical results shows good agreement with the reported data with an additional secondary phase corresponding to $Bi_2Fe_4O_9/Bi_2O_3$ has been appearing around 30^0 in 2θ range marked by stars. The average crystallite size was found to about 60 nm.

3.2 Surface Morphology:
Fig. 2 shows the surface morphological characteristics of $BiFeO_3$. The grains are non-uniform, agglomered and less densified with interconnected structure.

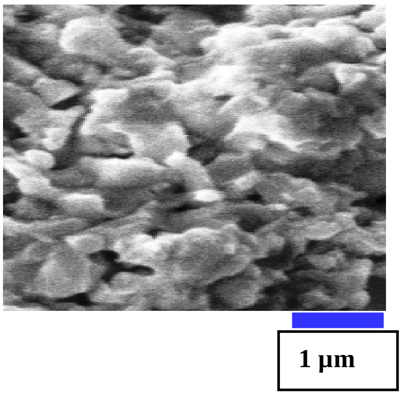

Fig. 2 Surface morphology of $BiFeO_3$ ceramic

3.3 Ferroelectric P-E loop:
Fig.3. shows the room temperature P-E hysteris loop of $BiFeO_3$ sample sintered at 700^0 C for 1 hour and exhibit ferroelectric nature. The loop shows proper saturation with enhanced saturation polarization (Ps), remnant polarization (Pr) and coercive electric field (Ec). The saturation polarization (Ps), remnant polarization (Pr) and coercive electric field (Ec) are Ps = 0.26 $\mu C/cm^2$, Pr = 0.11 $\mu C/cm^2$ and Ec = 3.2 kV/cm.

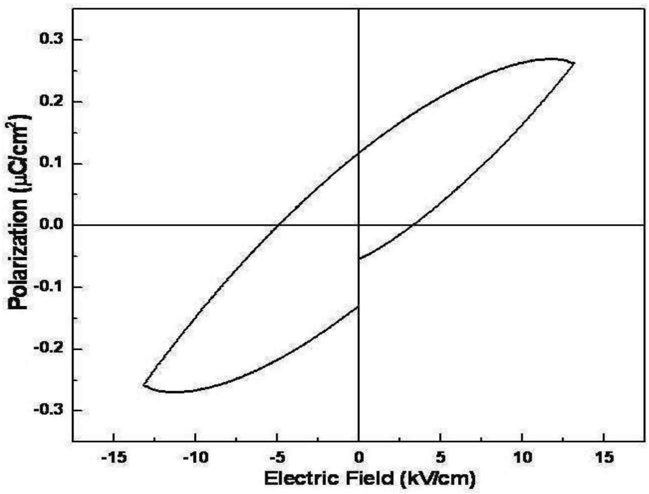

Fig.3. P-E Hysteris loop of $BiFeO_3$

3.4 Dielectric Constant-Temperature Measurement

Fig.4. shows a dielectric constant verses temperature measurement for $BiFeO_3$ sample in the temperature range 30 – 325 ^{0}C with the frequency range 10 kHz-1MHz. The dielectric constant shows a continuous increase with increasing temperature. The measured values of permittivity were ε ~ 2542, T=325°C and ε ~ 156 at room temperature for 10 kHz in $BiFeO_3$ ceramic.

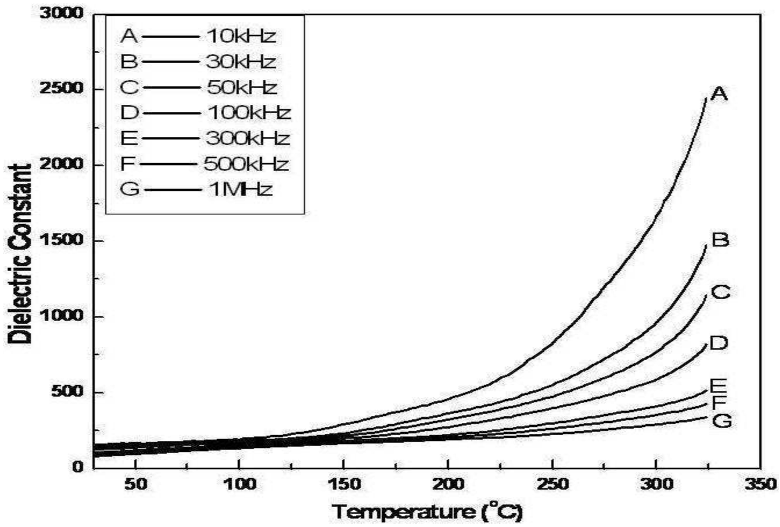

Fig.4. ε-T (f = Constant) of $BiFeO_3$ Sample

3.5. Dielectric loss-Temperature Measurement

Fig.5. shows a dielectric loss verses temperature plot of $BiFeO_3$ samples in the temperature range 30 – 325 ^{0}C at frequency range 10 kHz-1MHz. The dielectric loss exhibits a continuous increase with increasing temperature. The small values of dielectric loss was tanδ ~ 0.29, f = 10 kHz at room temperature and tanδ ~ 0.001, f = 1 MHz at temperature T = 400^0 C for $BiFeO_3$.

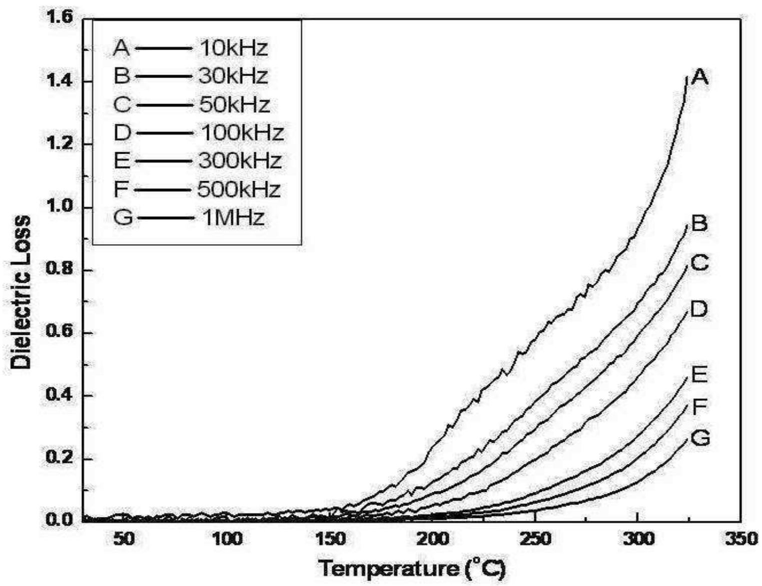

Fig.5. ε-tanδ (f = Constant) of $BiFeO_3$ Sample

3.5. Dielectric Constant- Frequency Measurement:

Fig.6 (a) shows variation of dielectric constant verses frequency obtained for $BiFeO_3$ sample at room temperature in the frequency range 10 kHz -1 MHz shows the dielectric constant decreases with increasing frequency.

Fig.6 (b) shows variation of dielectric loss verses frequency obtained for $BiFeO_3$ sample at room temperature in the frequency range 10 kHz -1 MHz shows the dielectric loss decreases with increasing frequency.

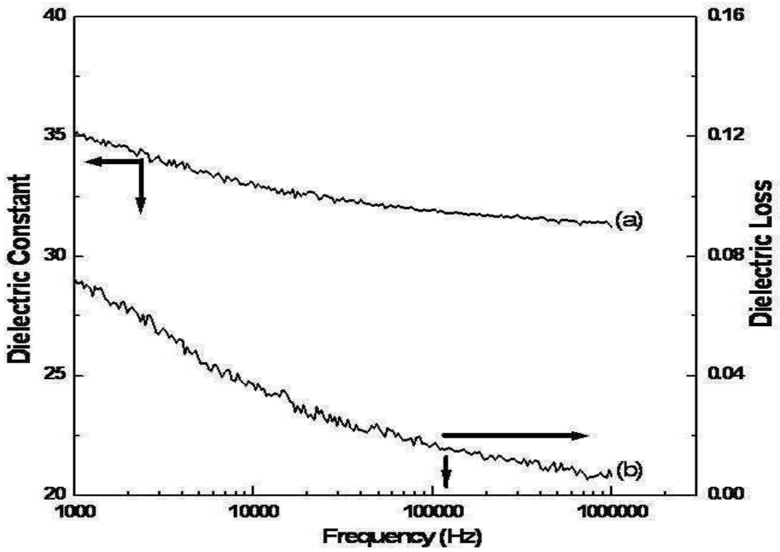

Fig.6 (a) ε-f (RT) plot and Fig. 6 (b) tanδ-f (RT) plot of $BiFeO_3$ ceramic

CONCLUSION

The solid state synthesized $BiFeO_3$ ceramics shows the rhombhohedral perovskite structure. The ferroelectric measurement reveals the ferroelectric nature of $BiFeO_3$ with saturation, remnant polarizations of $P_s = 0.26\ \mu C/cm^2$, $P_r = 0.11\ \mu C/cm^2$ respectively. The dielectric constant and loss as a function of temperature shows the dielectric constant and loss increases with increasing temperature. The room temperature dielectric measurement with frequency reveals the dielectric constant and loss decreases with increasing frequency for $BiFeO_3$ ceramics.

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